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# RELATIVE SUSCEPTIBILITY OF PONDEROSA PINES TO BARK BEETLE ATTACK

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U. S. Bureau of Entomology
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## INTRODUCTION

The possibility of obtaining sustained forest production in the ponderosa pine type of the Pacific Northwest through the application of the principles of selective logging has received special consideration by lumbermen and foresters, especially during the last few years, in connection with the development of forest practices under Article 10 of the Lumber Code. The objectives of selective cutting are to increase the value of the lumber product removed from the land and at the same time increase growth and reduce mortality so as to insure sustained yield forest production.

During the past two decades, destruction of ponderosa pine timber in this region through insect attack has been a major factor of mortality in virgin stands. Losses from barkbeetles on some logging operations have exceeded the timber cut. From 4 to 57 per cent of the mature stands on typical sample plots have been killed and the total annual loss in the region has run into billions of board feet. Many areas have suffered such a heavy depletion of the stand as to make them unprofitable logging chances.

One of the important considerations in the management of ponderosa pine timber lands is the reduction of insect mortality. A selective cutting which will remove those trees which are most susceptible to beetle attack may accomplish two desirable objectives - (1) the salvage of log values in trees which are not likely to remain alive for another cutting cycle and (2) improving the vigor of the stand as a whole so as to resist barkbeetle outbreaks.

The question of the relative susceptibility of ponderosa pines to beetle attack has received considerable study on the part of entomologists and silviculturists during the past decade. That the risk of beetle attack is greater for certain types of ponderosa pines than for others has been definitely shown a number of times. Dunning (3) in the study upon which he based his tree classification showed that the probability of insect loss was greatest in Classes 7, 5 and 4 when compared on the basis of basal area; while on the basis of number of trees, Classes 4, 2, 5 and 7 showed the highest risks in the order named. Person further verified these conclusions in a study which he reported in 1928 (5) in which he found that the beetles showed a decided preference for slow-growing trees, particularly in diameter classes between 20 and 30 inches and on the poorer sites. This preference was more marked during endemic than under epidemic conditions.

## RECENT DATA ON RELATIVE SUSCEPTIBILITY

This subject has received additional study each year during the annual survey of sample plots in the southern Oregon - northern California region from 1927 to 1932. Year by year an impressive amount of statistical data has been obtained which give added weight to previous conclusions, and show certain definite tendencies not apparent in the earlier work.

## SITE SELECTION

That site quality is an important consideration in determining the probability of beetle loss is amply demonstrated by the loss records on 15,680 acres of sample plots cruised in the southern Oregon region during the past twelve years. The relative losses sustained on the different sites in this region are shown in Table 1.

TABLE 1.

BEETLE LOSSES IN RELATION TO SITE QUALITY

(Basis - 15,680 acres of sample plots in southern Oregon and northern California. Period 1921-1932.)

| Site | Average Net Loss per acre per year Bd. Ft. | Percent Stand Killed Range | Percent Stand Killed Average |
|---|---|---|---|
| 3 - | 175 | 4.3% - 22.0% | 10.8% |
| 4 + | 232 | 3.7 - 30.0 | 14.6 |
| 4 | 298 | 20.5 - 37.7 | 27.8 |
| 4 - | 280 | 6.1 - 57.4 | 34.0 |

The above table indicates that insect losses bear a definite relationship to site quality either directly or indirectly. The percent of stand killed increased with a decrease in site quality. The net loss in board feet per acre, however, was somewhat lighter on Site 4- because of the smaller volume of the stand on such sites.

And yet, the above averages only tell a part of the story, for in some cases relatively poor sites have shown very low losses, while some good sites have sustained extremely high losses. The rate of tree growth and the degree of individual tree vigor is frequently independent of site

quality, and appears to play an important part in determining suscepti-bility in any particular stand. It is necessary, therefore, to look further than site quality for an index of bark beetle selection tendencies.

## TREE SELECTION

The type of tree showing the highest risk of bark beetle attack has been given the principal consideration in this study. Beetle killed trees have been compared with green trees in the same stands on the basis of diameter, age, growth rates, and crown vigor, in the hope of finding the particular set of characters most indicative of susceptibility.

## Diameter Selection

One of the simplest methods of comparing trees is on the basis of diameter, and cutting methods are frequently proposed on the basis of a minimum diameter limit. Person (5) compared the frequency-distribution by two-inch diameter classes of 5000 trees killed by western pine beetle with the frequency of these diameters in the stands of the San Joaquin area in California, and found a decided preference for trees between 20 and 30 inches d.b.h.

A similar comparison was made between 49,701 trees killed on the southern Oregon sample plots with a sample of 64,159 green trees on these areas. The comparison of frequency distribution by two-inch classes (Chart 1) shows a marked preference for trees between 20 and 32 inches, which is confirmation of the earlier results. However, diameter is a very inadequate criterion of relative risk and is recognized as a poor basis upon which to establish any good silvicultural marking practices.

## Selection by Tree Classes

The designation of certain types of trees showing more or less uniform characteristics which could be recognized by visual inspection in the field seemed to offer the best chance of determining relative susceptibility to bark beetle damage on a practical basis.

All recognizable factors, such as degree of dominance, (dominant, codominant, intermediate or suppressed) position, age, shape and character of crown, growth rate and general vigor, might have been studied separately. However, Dunning's proposed seven tree classes offered such a natural grouping of these various characteristics that it was used in the first study of mortality risks.

## Selection by Dunning's Tree Classes

During the 1927 insect survey, 19,680 acres of sample plots in southern Oregon and northern California were cruised and a comparison made on the basis of Dunning's tree classes between 13,160 beetle-killed trees and a random sample of 10,053 green trees. The details of this analysis were given in an unpublished report of February 1928, which is summarized in the following paragraphs:

The distribution of the beetle-killed trees as compared with the apportionment of different tree classes in the stand is shown in Table 2. The most susceptible tree types were shown to be Classes 7, 4 and 5. while the most resistant to beetle attack were Classes 1, 3, 2 and 6, in the order named. These results gave additional confirmation to the results reported by Dunning and Person.

TABLE 2.

DISTRIBUTION OF BEETLE-KILLED TREES
AS COMPARED WITH UNATTACKED TREES
Survey of 1927

| Dunning's Tree Class | Apportionment in Trees: Total Stand percent | Apportionment in Trees: Beetle-killed percent | Ratio of Mortality to stand |
|---|---|---|---|
| 1 | 21.7 | 5.0 | .23 |
| 2 | 9.9 | 6.9 | .70 |
| 3 | 14.9 | 9.5 | .64 |
| 4 | 11.7 | 19.5 | 1.67 |
| 5 | 31.7 | 45.0 | 1.42 |
| 6 | 6.0 | 4.9 | .82 |
| 7 | 4.1 | 9.0 | 2.20 |
| Total - | 100.% | 100.% | |

The tree classes selected for attack were all making an annual growth of less than one percent of the basal area and were largely the co-dominant, intermediate and suppressed types. Where dominant trees were attacked, such as in Class 5, it was found that the average volume of such trees was much lower than the average of the class as a whole, indicating that it was the poorer individuals in the class which were killed by insects. The beetles showed a preference for trees in diameter classes between 16 and 32 inches, which is principally due to the high proportion of trees struggling for dominance within this diameter range.

It was found that on good sites there was a marked selection of the suppressed, intermediate and codominant trees of Classes 4 and 7, while on the poorest sites the selective tendency became less marked and since trees of all classes were reduced in vigor, they all became more or less susceptible to attack and the proportion of loss found in the dominant classes 1, 3 and 5 greatly increased.

Again in 1932, in connection with the insect survey of sample plots in southern Oregon, a 10 percent cruise of the timber stand and 100 percent cruise of beetle losses was made on 14,000 acres of sample plots. Both green and beetle-killed trees were classified by Dunning's system so that an analysis of susceptibility was again possible. The results of this survey are given in Table 3, which again emphasizes the greater risk of classes 7, 4 and 5 to beetle attack and the comparative immunity of Classes 1, 3 and 2.

TABLE 3.

DISTRIBUTION OF BEETLE KILLED TREES AS COMPARED WITH AVERAGE STAND STRUCTURE ON 14,000 ACRES IN SOUTHERN OREGON. SURVEY OF 1932.

| Tree Class | Apportionment by Trees: Total Stand % | Beetle Killed % | Ratio of Mortality to stand | Apportionment by Volume: Total Stand % | Beetle Killed % | Ratio of Mortality to stand |
|---|---|---|---|---|---|---|
| 1 | 17.8 | 1.4 | .08 | 4.0 | .4 | .10 |
| 2 | 21.4 | 8.9 | .42 | 3.6 | 1.3 | .36 |
| 3 | 18.8 | 12.5 | .66 | 21.6 | 12.3 | .57 |
| 4 | 18.3 | 30.8 | 1.68 | 18.0 | 22.8 | 1.26 |
| 5 | 18.2 | 25.8 | 1.42 | 52.0 | 60.0 | 1.15 |
| 6 | 2.2 | 6.0 | 2.72 | .2 | .4 | 2.00 |
| 7 | 3.3 | 14.6 | 4.44 | .6 | 2.8 | 4.67 |
| Total - | 100.% | 100.% | | 100.% | 100.% | |

Since the plots in southern Oregon represent a fair sample of conditions in the virgin ponderosa pine stands of that section, it is interesting to note that in order to remove the susceptible tree classes 4, 5 and 7, a cutting would take 40.8 percent of the trees and 70.7 percent of volume.

## A More Critical Examination of Susceptibility

When Dunning proposed his tree classification, he recognized four major groups of factors which entered into the make-up of his seven tree classes. These were (1) four general age groups, (2) five degrees of dominance within the age groups, (3) crown development. and (4) degree of thrift; but for practical reasons it was obviously impossible to consider all of these factors separately, and to be useful in the field a system of tree classification had to group many of these factors together in order to have a workable number of tree classes.

However, from the standpoint of the types of trees selected by the beetles for attack, it was evident in the field that these broad tree classes tended to conceal differences in susceptibility within each group. It even seemed probable that there were certain types of trees within one class showing a greater disparity in relative risk to beetle attack than between different tree classes.

For the purpose of investigation, it seemed desirable to break down the Dunning tree classification into subclasses in order to try and isolate the specific characters which were most important in indicating susceptibility. Therefore an expansion of Dunning's tree classification into 16 classes was adopted and used in the field for the beetle surveys of 1928, 1929, 1930 and 1931.

DESCRIPTION OF TREE SUSCEPTIBILITY CLASSIFICATION.

The classification which was adopted for this study was based primarily upon the major factors of age and vigor. Four age groups similar to those recognized by Dunning were set up and numbered 1 to 4, as follows:

1. Young trees - less than 75 years, commonly referred to as "bull pines" or "black-jacks", with dark-brown to black, deeply ridged bark; tops usually pointed and branches in whorls.

2. Immature trees - from 75 to 150 years; trees still making height growth and with pointed tops; bark reddish-brown; branches in whorls.

3. Mature tree - 150 to 300 years; usually with round or sometimes with pointed tops; bark light-reddish-brown with moderately large plates between the fissures; incomplete whorls of branches with nodes indistinct; branches nearly all horizontal or drooping.

4. Overmature trees - over 300 years; with flat tops and making no further height growth; branches drooping, gnarled or crooked; bark light yellow in color, the plates usually very wide, long and smooth.

Then each of these age classes was subdivided into four sub-groups based upon relative crown vigor. These were designated by letters, as follows:

A. Full, vigorous crowns with a length of 55 percent or more of the total height and of average width or wider; foliage usually dense, long and dark gree; position of tree isolated or dominant (rarely co-dominant).

B. Fair to moderately vigorous crowns of average width or narrow-er and length less than 55 per cent of the total height; either short, wide crowns or long narrow ones but not sparse nor ragged; position, usually co-dominant but sometimes isolated or dominant.

C. Fair to poor crowns, very narrow and thin or represented only by a brush of foliage at the top. Foliage usually short and thin; position usually intermediate, sometimes codominant, rarely isolated.

D. Crowns of very poor vigor and of various shapes; foliage usually sparse and scattered; diameters decidedly subnormal considering age; position, suppressed or intermediate.

Thus by combining the four age groups with the four sub-groups of crown vigor, a total of sixteen classes was obtained which could be analyzed for relative susceptibility. (See Chart A and photographs) While at first glance such a classification might appear cumbersome, in actual field use it was found to be rather quickly grasped by the field men because only two decisions had to be reached - first, as to the tree's approximate age and then its degree of crown vigor.

According to definitions the comparison between the expanded classification and Dunning's classification would be as follows:

| Dunning's Classification | Susceptibility Study Classification |
|---|---|
| Class 1 | Classes 1A, 2A |
| Class 2 | Classes 1B, 2B |
| Class 3 | Class 3A |
| Class 4 | Classes 3B, 3C |
| Class 5 | Classes 4A, 4B, 4C |
| Class 6 | Classes 1C, 2C, 1D, 2D |
| Class 7 | Classes 3D, 4D |

Or in reverse order:

| Susceptibility Study Classification | | Dunning's Classification |
|---|---|---|
| Age group | Vigor group | |
| 1 | A, B, C, D | 1, 2, 6, 6 |
| 2 | A, B, C, D | 1, 2, 6, 6 |
| 3 | A, B, C, D | 3, 4, 4, 7 |
| 4 | A, B, C, D | 5, 5, 5, 7 |

In actual practice it was noted that most field men fail to follow Dunning's definitions in some cases, particularly in the designation of Class 6 trees. Trees of from 100 to 150 years of age, with fair crowns in an intermediate position which under the susceptibility classification, would be called Class 2C, are almost invariably placed by field men in Dunning's Class 2, instead of 6. It is difficult, therefore, to convert statistics taken under the susceptibility classification back into Dunning's classification and obtain the same results that would have been obtained through original classification under Dunning's system. Theoretically it should be possible, but in practice differences in interpretation give somewhat divergent results.

RELATIVE SUSCEPTIBILITY OF TREE CLASSES

During the bark beetle surveys in southern Oregon and Northern California for the four year period, 1928 to 1931, a total of 27,465 beetle killed trees on approximately 16,000 acres of sample plots were classified under this system, and a similar sample of 22,428 trees taken for comparison. This gave an ample basis for analyzing the type of tree most susceptible to bark beetle attack in this region. The results of this comparison are shown in Table 4, and also in graphical form in Charts #2 and #3.

TABLE 4.

| Tree Class | | Approtionment in Trees: Total Stand % | Beetle-killed % | Ratio of Mortality to stand | Relative Susceptibility Rank |
|---|---|---|---|---|---|
| 1. | A | 9.4 | 1.5 | .15 | 16 |
| | B | 5.6 | 2.5 | .44 | 13 |
| | C | 2.4 | 3.8 | 1.59 | 5 |
| | D | .2 | .5 | 2.50 | 2 |
| 2. | A | 9.1 | 2.8 | .30 | 15 |
| | B | 9.8 | 9.5 | .97 | 11 |
| | C | 5.5 | 14.1 | 2.58 | 1 |
| | D | 1.4 | 1.8 | 1.28 | 8 |
| 3. | A | 8.5 | 3.5 | .39 | 14 |
| | B | 10.5 | 11.7 | 1.11 | 10 |
| | C | 7.7 | 13.1 | 1.72 | 4 |
| | D | 2.9 | 4.0 | 1.36 | 7 |
| 4. | A | 9.1 | 4.3 | .47 | 12 |
| | B | 10.1 | 11.6 | 1.32 | 9 |
| | C | 5.6 | 12.4 | 2.38 | 3 |
| | D | 2.2 | 2.9 | 1.45 | 6 |

Chart #2 shows the percent of green trees in the normal virgin stands of southern Oregon and northern California distributed between the different tree classes, as indicated by the plot records; and also the distribution of trees killed by beetles during the period 1928-1931 between these same classes.

The ratio of occurrence of beetle losses in the various tree classes as compared with the apportionment of total green trees found in each class, indicates whether or not any particular tree class is favored by the beetles in making their attack. Thus, if 9~~8~~ per cent of the killed trees are found in class 2B, and 9 per cent of the green trees are also found in that class, the ratio will be 1, which indicates no particular preference. Ratios above 1 indicate that such trees are more freqiently found among the attacked trees, while ratios below 1 indicate corresponding immunity.

Chart 3 shows the ratio of susceptibility as determined from this particular study.

It should be noted that these results only apply in ponderosa pine stands where the western pine beetle (Dendroctonus brevicomis Lec.) and the pine flathead borer (Melanophila californica VD.) are the most active agents in causing loss. These results would not apply in the Rocky Mountain region where the Black Hills beetle (Dendroctonus ponderosae Hopk.) is the most aggressive pine destroyer, since studies in that region show that this bark beetle shows little or no preference for trees of poor vigor.

## RELATIVE SUSCEPTIBILITY BY AGE

There are several interesting points brought out by a comparison of relative susceptibility according to age alone or crown vigor irrespective of age. These comparisons are made in Tables 5 and 6.

TABLE 5.
RELATIVE SUSCEPTIBILITY BY AGE

| Age Group | Ages | Apportionment in Trees: Total Stand | Apportionment in Trees: Beetle-Killed | Ratio of Mortality to Stand |
|---|---|---|---|---|
| | | % | % | |
| 1 | (75-) | 17.6 | 8.3 | .46 |
| 2 | (75-150) | 25.8 | 28.2 | 1.15 |
| 3 | (150-300) | 29.6 | 32.3 | 1.05 |
| 4 | (300-plus) | 27.0 | 31.2 | 1.16 |

In comparing relative susceptibility by ages, it will be noted that there is very little difference in trees over 75 years of age. As has been frequently noted, trees of the bull pine type (age group 1) which rarely exceed 16 inches in diameter in Oregon's site 4, are very resistant to bark beetle attack. Since the study did not include trees below 10 inches in diameter, and since the average tree of 75 years is only about 10 inches, most trees of this age group were too small to be included in the study.

## RELATIVE SUSCEPTIBILITY BY CROWN VIGOR

In comparing the importance of crown vigor, it will be noted that relative susceptibility increases very rapidly with a decrease in vigor until sub-group D is reached. Trees in this group are so poor in vigor and have such thin dry bark, that apparently they are not acceptable as beetle breeding material, so they are not killed as often as one might suppose.

TABLE 6.
RELATIVE SUSCEPTIBILITY BY CROWN VIGOR

| Crown Group | Apportionment in Trees | | Ratio of Mortality to Stand |
|---|---|---|---|
| | Total Stand % | Beetle-Killed % | |
| A (Full vigor) | 36.0 | 12.0 | .33 |
| B (Moderate vigor) | 36.0 | 35.3 | .98 |
| C (Poor vigor) | 21.2 | 43.4 | 2.05 |
| D (Very poor vigor) | 6.8 | 9.3 | 1.37 |

It is evident from these two comparisons that crown vigor is much more important in determining susceptibility than merely age. In other words, the fact that a tree is old does not necessarily make it a poor risk, while the character of its crown and its position in the stand are much more important considerations.

On the basis of the data obtained in this study, the rank of the different tree classes according to degree of susceptibility to bark beetle attack, is as shown in Table 7.

## TABLE 7.

## RELATIVE SUSCEPTIBILITY OF TREE CLASSES

| Tree Class # | Tree Class ## | Tree Types | Ratio | Rank |
|---|---|---|---|---|
| | | **Most Susceptible Types** | | |
| | | Intermediate crowns of poor vigor | | |
| 2C | 6 | Age 75-150 years | 2.58 | 1 |
| | | Suppressed crowns of very poor vigor | | |
| 1D | 6 | Age under 75 years | 2.50 | 2 |
| | | Intermediate crowns of poor vigor | | |
| 4C | 5 | Age 300 years plus | 2.38 | 3 |
| 3C | 4 | Age 150-300 years | 1.72 | 4 |
| 1C | 6 | Age under 75 years | 1.69 | 5 |
| | | Suppressed crowns of very poor vigor | | |
| 4D | 7 | Age 300 years plus | 1.45 | 6 |
| 4D | 7 | Age 150-300 years | 1.35 | 7 |
| 2D | 6 | Age 75-100 years | 1.28 | 8 |
| | | Codominant crowns of moderately good vigor | | |
| 4B | 5 | Age 300 years plus | 1.22 | 9 |
| 3B | 4 | Age 150-300 years | 1.11 | 10 |
| | | **Resistant Types** | | |
| | | Codominant crowns of moderately good vigor | | |
| 2B | 2 | Age 75-150 years | .97 | 11 |
| | | Dominant crowns of good vigor | | |
| 4A | 5 | Age 300 years plus | .47 | 12 |
| | | Codominant crowns of moderately good vigor | | |
| 1B | 2 | Age under 75 years | .44 | 13 |
| | | Dominant trees of good vigor | | |
| 3A | 3 | Age 150-300 years | .39 | 14 |
| 2A | 1 | Age 75-150 years | .30 | 15 |
| 1A | 1 | Age under 75 years | .15 | 16 |

# Susceptibility classification ## Dunning's classification

In some cases the exact order given above probably has little significance, particularly in classes such as 1D, which are represented by a very small number of trees. Except for one or two cases which are out of line, the logical order of susceptibility from poor risk to good would first be by the crown groups C, D, B and A; and then according to age, 4, 3, 2 and 1.

The analysis of relative susceptibility to beetle attack under the expanded classification verifies previous conclusions in many important respects and also shows that within certain of the Dunning tree classes there is considerable variation as to beetle risk. An inspection of Table 7 illustrates these conclusions. In this table the tree classes are listed in the order of their susceptibility. The first ten classes are all represented in the losses more frequently than such classes occur in the stand, while number 11 to 16 are less frequently killed.

As was shown in previous studies, Dunning's tree classes 1, 3 and 2 were found to be the most resistant types. Added to these, however, is Class 4 A (Dunning's 5, with dominant crowns of good vigor) which is only slightly less susceptible than vigorous trees of Class 3 and This is probably the most significant finding of the study from a forest management standpoint, since it shows that these large trees are good risks as far as beetle kill is concerned. Apparently, dominant trees of Dunning's Class 1, as they grow older, become Class 3 and later still become dominants of Class 5. Their roots occupy all the surrounding ground space to the exclusion of competing trees and even reproduction. They remain thrifty and vigorous and nearly as capable of warding off insect attack in their old age as they were in their youth. Such trees can maintain their dominance and hold on to life for many years, even after having reached an age of 300. Many mature ponderosa pines are around 450 years of age and one felled tree recently examined in southern Oregon was 750 years old. Undoubtedly such veterans have withstood many barkbeetle outbreaks.

On the other hand, overmature trees of Dunning's Class 5, with crowns of poor vigor, are among the most susceptible to beetle attack. There is also a wide spread between two types of Dunning's Class 4 - those with poor crowns (Class 3C) take fourth place in order of susceptibility while those with fairly good crowns (Class 3B) rank in 10th place. Trees of Dunning's Class 6 and 7 are all susceptible and since those trees are few in number and of little value in the stands the relative susceptibility of the subgroups is of minor importance.

It is evident that the barkbeetles in ponderosa pine stands of this region have been acting as Nature's silvicultural agents in removing the intermediate, suppressed and codominant trees as these are crowded out by the rise of the dominants. They are primarily the agents which relieve the pressure of too much tree competition or of critical growth conditions. Unfortunately they sometimes carry these normal activities too far and during epidemics may wipe out all of the mature trees in a stand.

## BEETLE SELECTION OF TREES IN GROUPS

One very obvious characteristic of western pine beetle infestation is the tendency to select trees of intermediate, codominant and suppressed crown development which are growing in groups, while isolated trees are much less frequently taken. This suggests that spacing may be a very important consideration, especially during drought conditions when groupwise trees are forced to compete with each other for whatever soil moisture there may be in the relatively small area surrounding their location. During such periods large groups on normally good sites may suffer from a more critical shortage of moisture than widely spaced trees on poor sites

which are adjusted to a perennially inadequate supply. This may be one of the reasons why group infestation is so characteristic of outbreaks on good sites, while on poor sites infestations are usually more widely dispersed, both in groups and in isolated trees.

## APPLICATION TO MARKING PRACTICE

This study has been concerned primarily with the determination of the relative hazard from bark beetle attack of certain types of trees in the stand. These types can now be recognized with a fair degree of certainty under average conditions of beetle infestation. This is of interest not only from a purely academic viewpoint but from the standpoint of direct application to silvicultural practices.

Once the more susceptible types of trees are known it is possible to modify marking practice so as to include such trees in the first cut. Such removal may accomplish one or both of two objectives - first, the salvage of valuable trees which have a small chance of lasting until the next cut; and secondly, the reduction of the chances of a beetle outbreak through removal of the trees most likely to develop infestation.

## SALVAGING TREES OF HIGH RISK

Present marking practice in the ponderosa pine forests of the National Forests and Indian Reservations of this region in which 80 percent or more of present mature stands are removed, so nearly eliminates all types of beetle susceptible trees that the questions of salvaging values and reducing the threat of beetle losses are usually solved. Under this

more or less standard marking practice all trees of high beetle risk, except a few intermediate and suppressed trees of low value in the younger age groups, have been marked for cutting.

However, under a system of light selection cutting, if in the first cut a smaller volume of timber is to be removed over a larger acreage, then the question of relative beetle risk becomes important. Trees of the highest risk obviously should be removed first, and the others cut in order of their susceptibility rank until the percent of volume which it is desired to remove has been reached. This is illustrated in Table 8, using the stand structure shown to exist on the 16,000 acres of sample plots in southern Oregon.

TABLE 8.
SELECTION OF HIGH RISK TREES

| Relative Risk | Tree Class | | Average Diameter | Average Volume Bd.feet | Value | Stand Structure by Volume: Percent by Class | Stand Structure by Volume: Cumulative percent |
|---|---|---|---|---|---|---|---|
| Susceptible Types | | | | | | | |
| 1 | 2C | 6 | 16" | 160 | Low | 1.1 | 1.1 |
| 2 | 1D | 6 | 11" | 30 | Unmerch. | --- | 1.1 |
| 3 | 4C | 5 | 28" | 1280 | High | 9.1 | 10.2 |
| 4 | 3C | 4 | 21" | 540 | High | 5.3 | 15.5 |
| 5 | 1C | 6 | 12" | 60 | Unmerch. | .2 | 15.7 |
| 6 | 4D | 7 | 18" | 350 | Low | 1.0 | 16.7 |
| 7 | 3D | 7 | 14" | 140 | Low | .5 | 17.2 |
| 8 | 2D | 6 | 12" | 70 | Low | .1 | 17.3 |
| 9 | 4B | 5 | 32" | 1790 | High | 23.0 | 40.3 |
| 10 | 3B | 4 | 26" | 930 | High | 12.4 | 52.7 |
| Resistant Types | | | | | | | |
| 11 | 2B | 2 | 19" | 300 | Low | 3.7 | 56.4 |
| 12 | 4A | 5 | 35" | 2200 | High | 25.5 | 81.9 |
| 13 | 1B | 2 | 14" | 100 | Low | .7 | 82.6 |
| 14 | 3A | 3 | 28" | 1100 | High | 11.9 | 94.5 |
| 15 | 2A | 1 | 20" | 370 | Low | 4.3 | 98.8 |
| 16 | 1A | 1 | 14" | 100 | Low | 1.2 | 100.0 |

If in this area it were found desirable to remove 15 percent of the stand then the first five tree classes should be the first to come out.

A 40 per cent cut would take the first nine classes, and a 53 per cent cut would take all of the high risk trees. Such a cut would leave a lot of high valued lumber in class 4A and 3A trees and would require the removal of a great many trees of very low merchantability, so that from a value selection standpoint the cutting would not be particularly desirable.

In order to remove trees most liable to succumb to bark beetle attack, it is not desirable to make a horizontal selection cutting based on age in which merely the mature and overmature trees are removed. Instead the cutting should be based upon crown vigor and a vertical selection made of the intermediate, suppressed and codominant trees throughout all age classes, but naturally favoring the leaving of younger trees in preference to older ones. The only difference in such a marking from present marking practice would be in the direction of taking small trees of poor crown development, especially when in groups, and the leaving of older trees of large dominant crowns, but other conditions, such as wind damage, may make it desirable to cut the large trees. Such a marking has little or no relation to economic selection marking in which an attempt is made to liquidate trees of high value, since a high percentage of low valued trees are of unthrifty types which are among the most susceptible to bark beetle attack. On the other hand, many high value trees are thrifty, vigorous individuals which represent the lowest of beetle risks.

An interesting comparison was made recently between three types of marking (1) standard Forest Service practice, (2) bark beetle susceptibility, and (3) economic selection based upon Anderson's study of tree values (1). A 30-acre plot on the Malheur National Forest was marked independently by the three systems and the results compared as follows:

| | Take | Leave |
|---|---|---|
| Standard Forest Service | 80% | 20% |
| Bark beetle susceptibility | 70% | 30% |
| Economic selection | 57% | 43% |

The standard Forest Service marking and the bark beetle susceptibility marking agreed on 90% of the trees. The only disagreement was in the case of some of the older dominants which the bark beetle susceptibility marking did not take, but which were cut because of possible wind damage and for economic reasons. The economic selection marking and the bark beetle susceptibility marking agreed on 60 per cent of the trees and disagreed on 40 per cent. The greatest disagreement was in the marking of the smaller intermediate and suppressed trees of low log value.

## INFLUENCE OF SELECTIVE CUTTING UPON BARK BEETLE OUTBREAKS

While a stand which has been thinned of the more susceptible trees should in all reason be in better shape to resist bark beetle epidemics, there is no assurance that such stands will be immune to further losses. During periods of bark beetle epidemics, trees of all classes may be killed with little regard to apparent vigor. Also in "fringe type" timber or on areas suffering from the effects of drought, all types of trees are reduced in vigor and resistance to bark beetle attack, and tend to become nearly equal in susceptibility. There are many examples to show that on the poorer sites and in fringe type timber, it is futile to leave any but the youngest and most vigorous trees.

This and other studies show that growth conditions in the stand determines in a large measure, the beetle damage which may occur. Whatever can be done through thinnings to release trees from competition, and to improve growth, should be reflected in a lessening of beetle damage.

The measures necessary to accomplish these objectives are similar in every respect. The types of trees which should be cut from the growth improvement standpoint, are also those which should be removed in order to reduce mortality. While selection cuttings may not solve the problem of all future bark beetle damage, it is at least a step in the right direction of improving the chances of ponderosa pine stands to escape such injury. Thus, in large measure, the solution of the pine beetle problem lies in the application of the principles of good silviculture.

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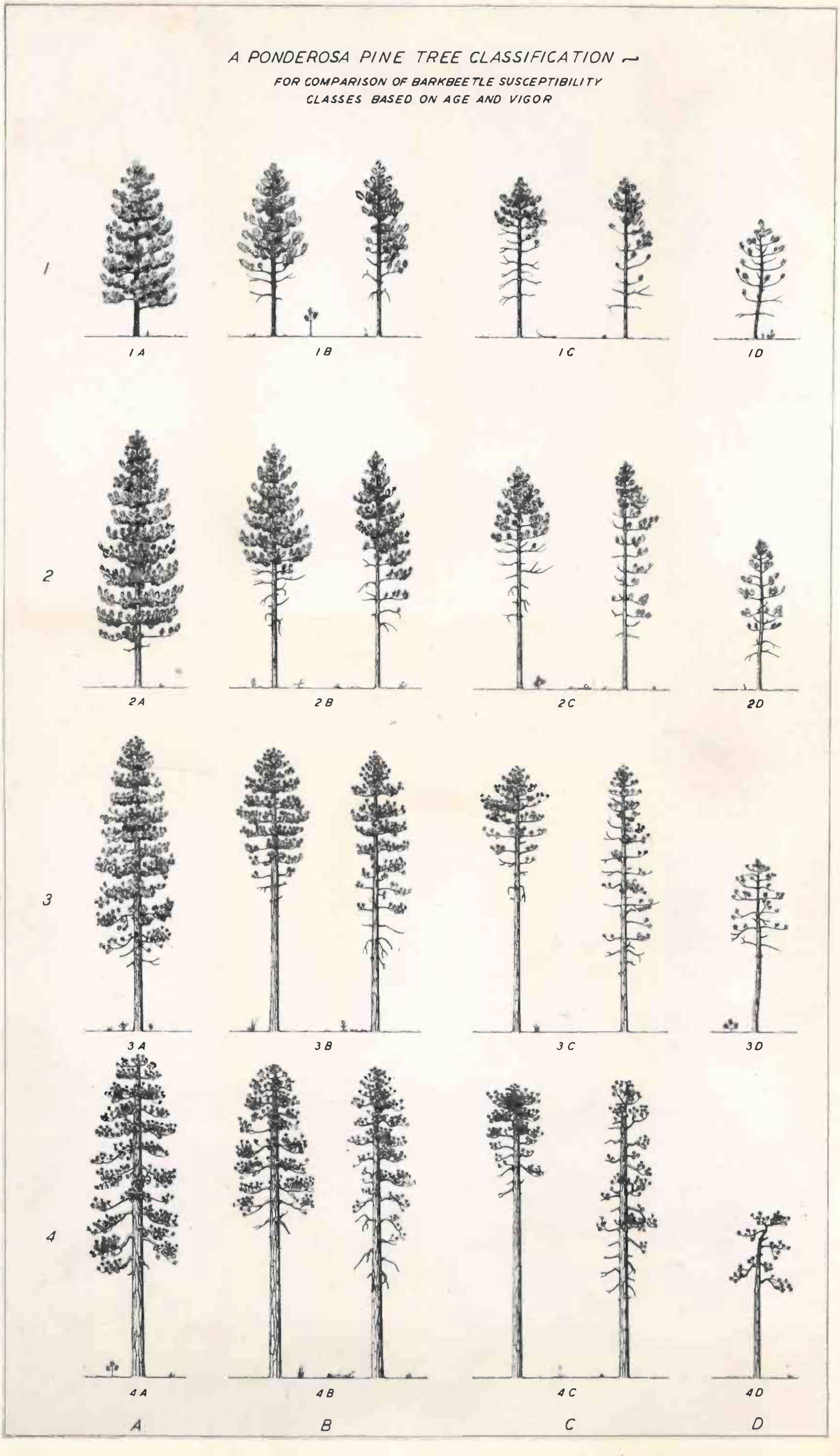
Chart A


A PONDEROSA PINE TREE CLASSIFICATION —
FOR COMPARISON OF BARKBEETLE SUSCEPTIBILITY
CLASSES BASED ON AGE AND VIGOR
1
2
3
4
1A
1B
1C
1D
2A
2B
2C
2D
3A
3B
3C
3D
4A
4B
4C
4D
A
B
C
D

1A

1A

1B

1B

RESISTANT TYPES

1C

1C

1D

SUSCEPTIBLE TYPES

2A

2A

2A

2B

RESISTANT TYPES

2C

2C

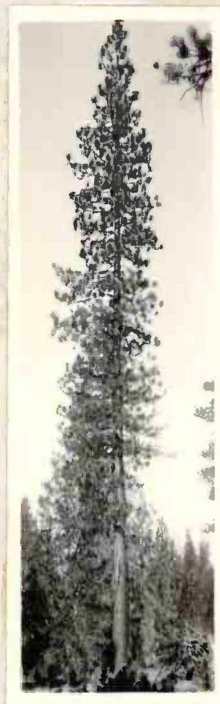
2C

2D

SUSCEPTIBLE TYPES

3A

3A



3B

3B

RESISTANT TYPES

3C

3C

3C

3D

SUSCEPTIBLE TYPES

4A

4A

4B

4B

RESISTANT TYPES

SUSCEPTIBLE TYPES

4C

4C

4C

4D

VERY SUSCEPTIBLE TYPES

CHART I.

DISTRIBUTION OF GREEN ANDBEETLE KILLED TREES
BY DIAMETER CLASSES

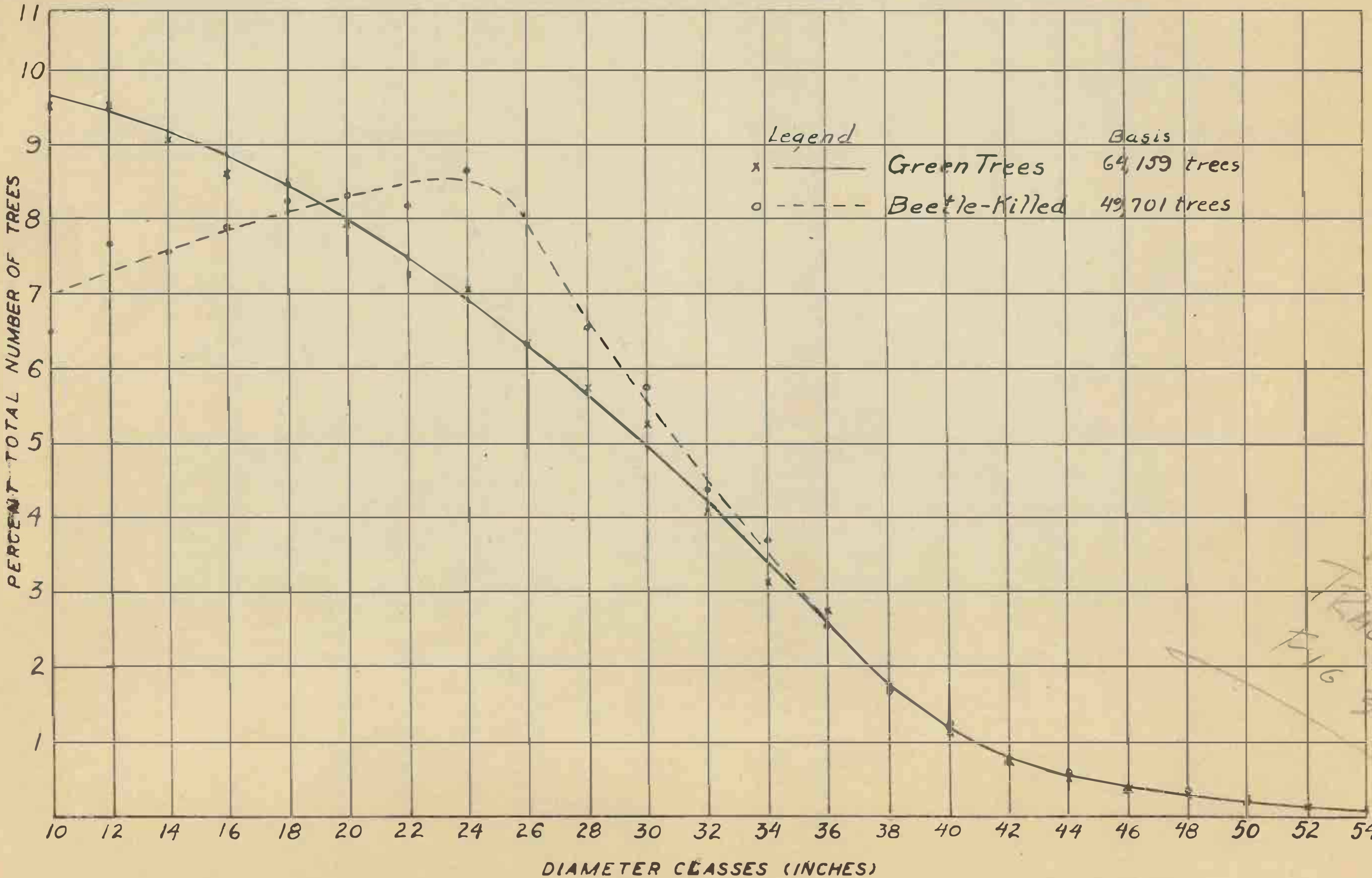


CHART 2.

DISTRIBUTION OF GREEN AND BEETLE KILLED TREES IN STAND
BY TREE CLASSES

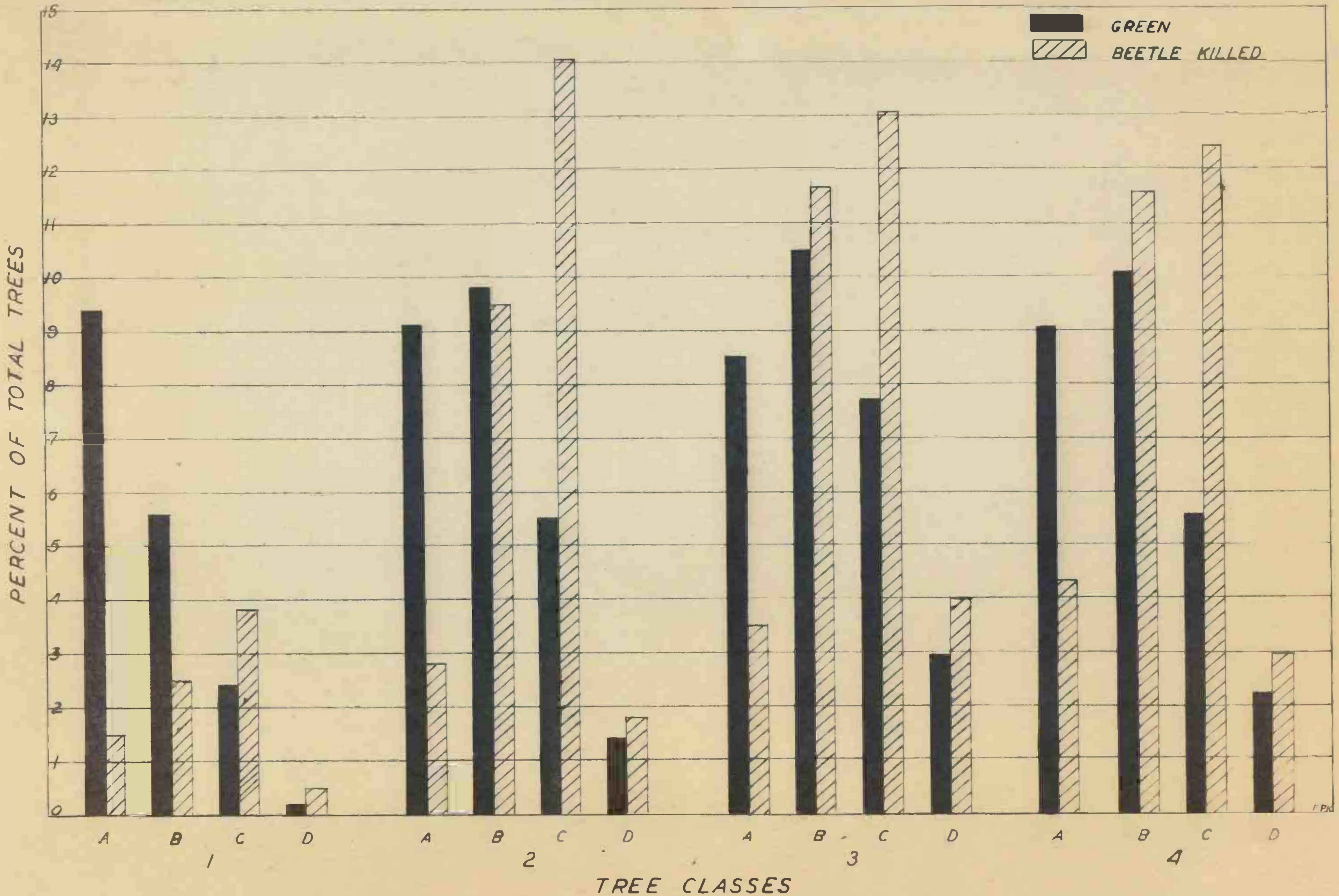
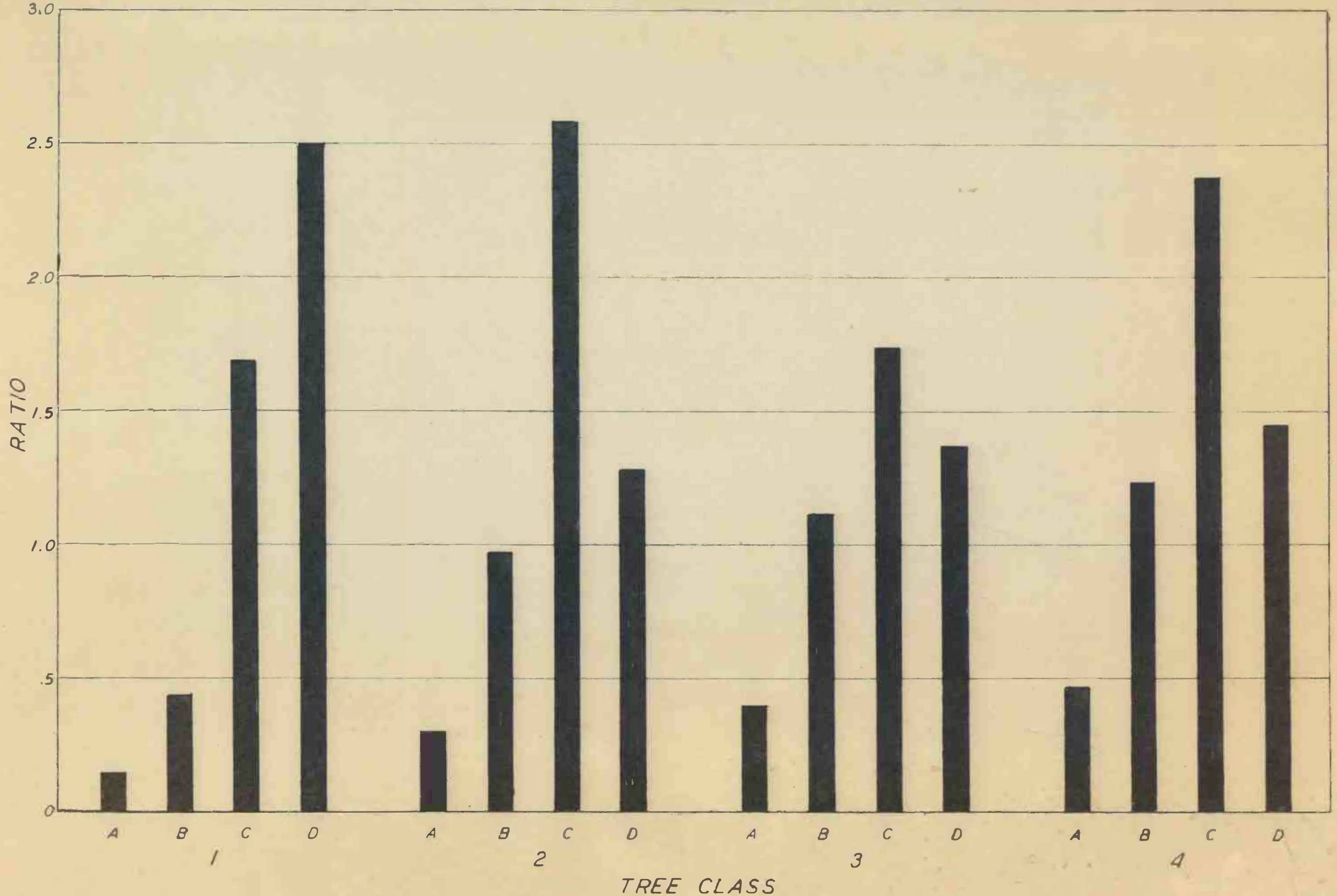


CHART 3.

RELATIVE INSECT SUSCEPTIBILITY.

APPORTIONMENT OF INSECT LOSSES BETWEEN TREE CLASSES TO APPORTIONMENT OF TREE CLASSES IN THE STAND.



Copy to Mr. [illegible]

MEMORANDUM FOR DR. K. A. SALMAN.

RE: CRITICISM OF KEEN'S ARTICLE ON RELATIVE SUSCEPTIBILITY OF PONDEROSA PINE TO BARKBEETLE ATTACK.

In his recent article on The Relative Susceptibility of Ponderosa Pine to Bark Beetle Attack* Keen has proposed to classify ponderosa p ne into sixteen groups according to their relative susceptibility to barkbeetle attack. He has based his classification on the percentage of loss within each of his tree classification groups expressed as a ratio of number of trees in a group divided into the number of trees dying within the group. Such a susceptibility rating gives a clear picture of the expected loss within each tree class, but it fails completetely to show the complete picture of the volume loss in any stand of timber. For example, he shows that class 1 D is the most susceptible tree class in his classification, but this tree class has contributed but two hundredths of one percent of the total volume loss for the area sampled. Contrast this with class 4 B which rates ninth place in his susceptibility classification and we find that this one class out of 16 has alone contributed 27.3 percent of the total stand loss. Referring to Figure 1, which shows the percentage of volume loss by each of his susceptibility classes arranged from 1 to 16, it is clear that these classes are in no way correlated with volume loss.

Figure 2 shows the same figures as in figure 1, but arranged in order of the magnitude of the volume loss ranging from maximum to minimum. On the basis of percentage colume loss rating these classes appear as follows:

| Relative volume loss rating | Keen Tree class | Keen Relative susceptibility | Percent of total volume loss |
|---|---|---|---|
| 1 | 4 B | 9 | 27.3 |
| 2 | 4 C | 3 | 20.8 |
| 3 | 3 B | 10 | 14.2 |
| 4 | 4 A | 13 | 12.5 |
| 5 | 3 C | 4 | 9.3 |
| 6 | 3 A | 14 | 5.0 |
| 7 | 2 B | 11 | 3.7 |
| 8 | 2 C | 2 | 3.0 |
| 9 | 2 A | 15 | 1.3 |
| 10 | 4 D | 7 | 1.1 |
| 11 | 3 D | 6 | 0.7 |
| 12 | 1 B | 12 | 0.3 |
| 13 | 1 C | 5 | 0.3 |
| 14 | 1 A | 16 | 0.2 |
| 15 | 2 D | 8 | 0.2 |
| 16 | 1 D | 1 | 0.02 |

*Journal of Forestry, Oct. 1936, Vol. 34, No. 10: pp 919-927.

Figure 3 shows the percentage of stand volume together with the percentage of total loss for each tree class grouped according to Keen's susceptibility rating. This shows that the ratio of percentage volume loss to percentage total stand volume is much greater in his low susceptibility groups, as he has shown in his article, but it also shows that his highly susceptible group, 1 to 8 inclusive, contains only 18 percent of the total stand volume with his 4 C and 3 C groups alone making up 15 of this 18 percent, so that regardless of the outcome in the other 6 classes, here it will have very little bearing on the tatal volume loss. To follow this reasoning still further, again refer to tree classes 1 D and 4 B rated 1 and 9 respectively in Keen's susceptibility classification. Class 1 D lost 8 trees out of 51 or a loss percentage for the class of about 16 percent. This 16 percent loss in this group, however, only carried a volume loss of 240 board feet. Class 4 B lost 189 trees out of a total of 2242 or an approximate class loss of 8 percent. However, this 8 percent loss in class 4 B has contributed 336,520 board feet to the total volume loss, or over 1400 times as much volume as class 1 D which actually lost 16 perœnt of the trees.

Table I.

| Tree Class | | Total stand per 1000 acres No. trees | Percent | Volume | Percent | 4 yr. total loss per 1000 acres No. trees | Percent | Volume | Percent | Rel. Sus. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | A | 1983 | 8.8 | 198300 | 1.1 | 24 | 1.5 | 2400 | .20 | 16 |
| | B | 1160 | 5.1 | 116000 | 0.7 | 40 | 2.5 | 4000 | .32 | 12 |
| | C | 548 | 2.4 | 32880 | 0.2 | 62 | 3.8 | 3720 | .30 | 5 |
| | D | 51 | 0.2 | 1530 | 0.01 | 8 | 0.5 | 240 | .02 | 1 |
| 2 | A | 1987 | 8.8 | 735190 | 4.2 | 45 | 2.8 | 16650 | 1.35 | 15 |
| | B | 2181 | 9.7 | 654300 | 3.7 | 153 | 9.5 | 45900 | 3.72 | 11 |
| | C | 1409 | 6.3 | 225440 | 1.3 | 229 | 14.1 | 36640 | 2.97 | 2 |
| | D | 344 | 1.5 | 24080 | 0.1 | 29 | 1.8 | 2030 | .17 | 8 |
| 3 | A | 1940 | 8.6 | 2134000 | 12.1 | 56 | 3.5 | 61600 | 5.00 | 14 |
| | B | 2387 | 10.6 | 2219910 | 12.6 | 189 | 11.7 | 175770 | 14.25 | 10 |
| | C | 1840 | 8.2 | 993600 | 5.6 | 212 | 13.1 | 114480 | 9.28 | 4 |
| | D | 674 | 3.0 | 94360 | 0.5 | 65 | 4.0 | 9100 | .74 | 6 |
| 4 | A | 1997 | 8.9 | 4393400 | 24.9 | 70 | 4.3 | 154000 | 12.49 | 13 |
| | B | 2242 | 10.0 | 4013180 | 22.8 | 188 | 11.6 | 336520 | 27.29 | 9 |
| | C | 1290 | 5.7 | 1651200 | 9.4 | 200 | 12.4 | 256000 | 20.76 | 3 |
| | D | 489 | 2.2 | 146700 | 0.8 | 47 | 2.9 | 14100 | 1.14 | 7 |
| Total | | 22522 | 100.0 | 17634070 | 100.0 | 1617 | 100.0 | 1233150 | 100.0 | |

Using Keen's correction factor for his classes to Dunning's, the percentage volume loss for each of Dunning's classes has been figured and appears in Figure 4. These are as follows:

| Dunning's classes | Percent volume loss |
|---|---|
| 1 | 1.54 |
| 2 | 4.04 |
| 3 | 5.00 |
| 4 | 23.54 |
| 5 | 60.53 |
| 6 | 3.47 |
| 7 | 1.88 |
| Total | 100.00 |

Table 2 has been prepared to show the volume cut and the loss taken by using Dunning's and Keen's methods of marking. Using Dunning's method 76.6 percent of the volume would have been removed together with 86.0 percent of the loss. With Keen's light cut taking classes 1 to 8 inclusive, 18 percent of the volume would be removed together with but 35.4 percnet of the loss. In KeenIs heavy cut, taking classes 1 to 11 inclusive, 57 percent of the volume would be removed together with 80.6 percent of the loss. Actually the chief difference in Dunning's marking practice and that of Keen with his heavy cutting method is that the latter leaves class 4 A while the former would include that in his cut. On the basis of the figures whech are here presented, it does not appear that Keen's classification has any marked advantage over that proposed by Dunning, and further, Keen's rating of relative susceptibility does not give a clear picture of volume loss, which is, after all, the factor which is pf prime interest to the lumberman, the Forester and the entomologist.

Respectfully submitted,

Ralph C. Hall
Assistant Entomologist

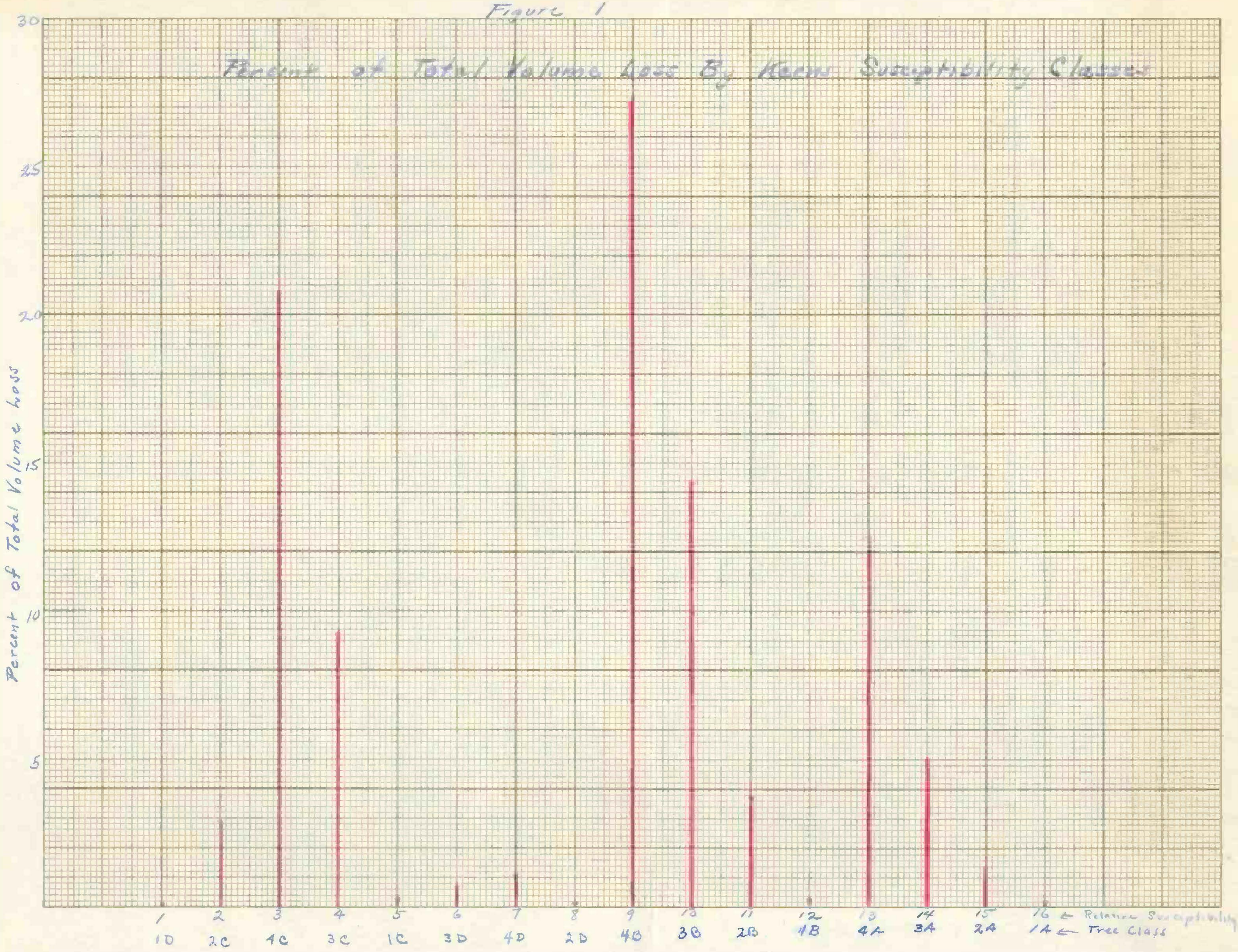
Berkeley, California
May 23, 1938

Table II

Table showing the percent of volume removed cutting according to Dunning's and Keen's systems, together with the amount of loss taken in each cut

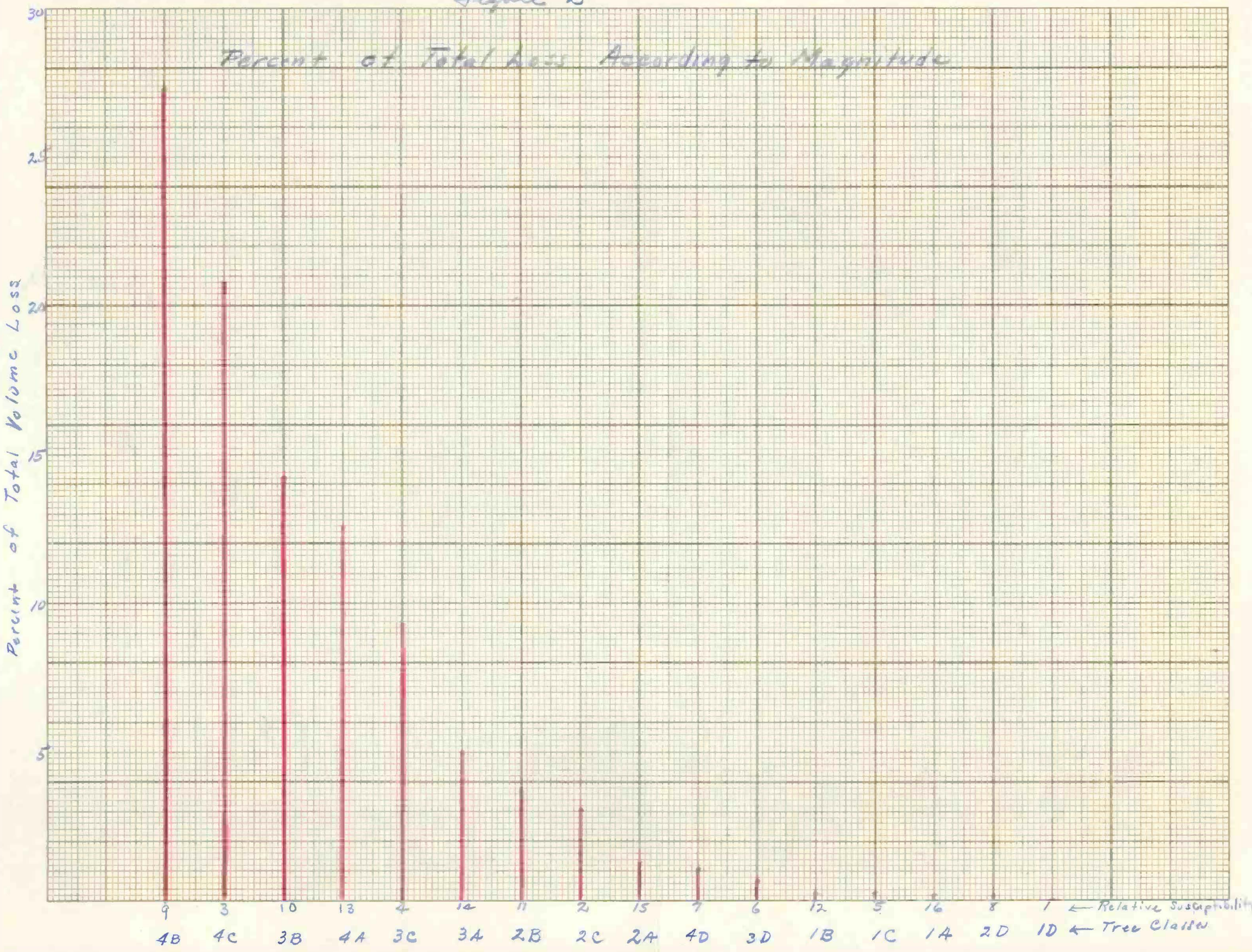
| Marking system | Remove | | | Leave | | |
|---|---|---|---|---|---|---|
| | Tree class | % stand vol. | % vol.loss | Tree class | % stand vol. | % vol.loss |
| Dunning | D 4 | 18.2 | 23.6 | 1 | 5.3 | 1.5 |
| | 5 | 57.1 | 60.6 | 2 | 4.4 | 4.0 |
| | 7 | 1.3 | 1.8 | 3 | 12.1 | 5.0 |
| | | | | 6 | 1.6 | 3.5 |
| | Total | 76.6 | 86.0 | Total | 23.4 | 14.0 |
| Keen Light | K. 1D | .01 | .02 | 4B | 22.8 | 27.3 |
| | 2C | 1.3 | 3.0 | 3B | 12.6 | 14.3 |
| | 4C | 9.4 | 20.8 | 2B | 3.7 | 3.7 |
| | 3C | 5.6 | 9.3 | 4A | 24.9 | 12.5 |
| | 1C | 0.2 | 0.3 | 3A | 12.1 | 5.0 |
| | 3D | 0.5 | 0.7 | 1B | .7 | .3 |
| | 4D | 0.8 | 1.1 | 2A | 4.2 | 1.4 |
| | 2D | 0.1 | .2 | 1A | 1.1 | .2 |
| | Total | 18.0 | 35.4 | Total | 43.0 | 64.6 |
| Keen Heavy | K. 1D | .01 | .02 | 4A | 24.9 | 12.5 |
| | 2C | 1.3 | 3.0 | 3A | 12.1 | 5.0 |
| | 4C | 9.4 | 20.8 | 1B | 0.7 | 0.3 |
| | 3C | 5.6 | 9.3 | 2A | 4.2 | 1.4 |
| | 1C | 0.2 | 0.3 | 1A | 1.1 | 0.2 |
| | 3D | 0.5 | 0.7 | | | |
| | 4D | 0.8 | 1.1 | | | |
| | 2D | 0.1 | 0.2 | | | |
| | 4B | 22.8 | 27.3 | | | |
| | 3B | 12.6 | 14.3 | | | |
| | 2B | 3.7 | 3.7 | | | |
| | Total | 57.0 | 80.6 | | 43.0 | 19.4 |

Figure 1



Percent of Total Volume Loss By Known Susceptibility Classes
Percent of Total Volume Loss
30
25
20
15
10
5
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 ← Relative Susceptibility
1D 2C 4C 3C 1C 3D 4D 2D 4B 3B 2B 1B 4A 3A 2A 1A ← Tree Class

Figure 2


Percent of Total Loss According to Magnitude
Percent of Total Volume Loss
30
25
20
15
10
5
9 3 10 13 4 14 11 2 15 7 6 12 5 16 8 1 ← Relative Susceptibility
4B 4C 3B 4A 3C 3A 2B 2C 2A 4D 3D 1B 1C 1A 2D 1D ← Tree Classes

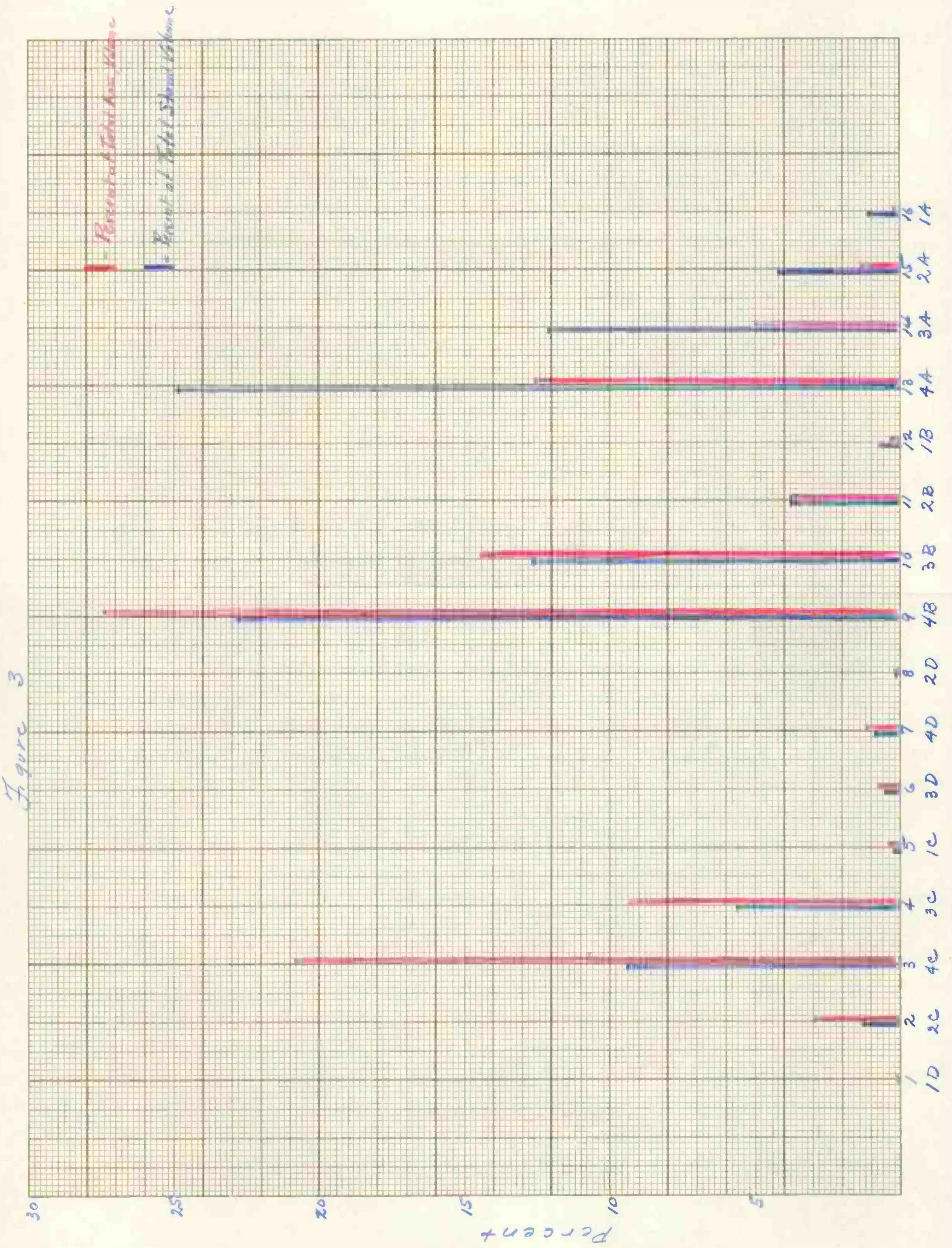
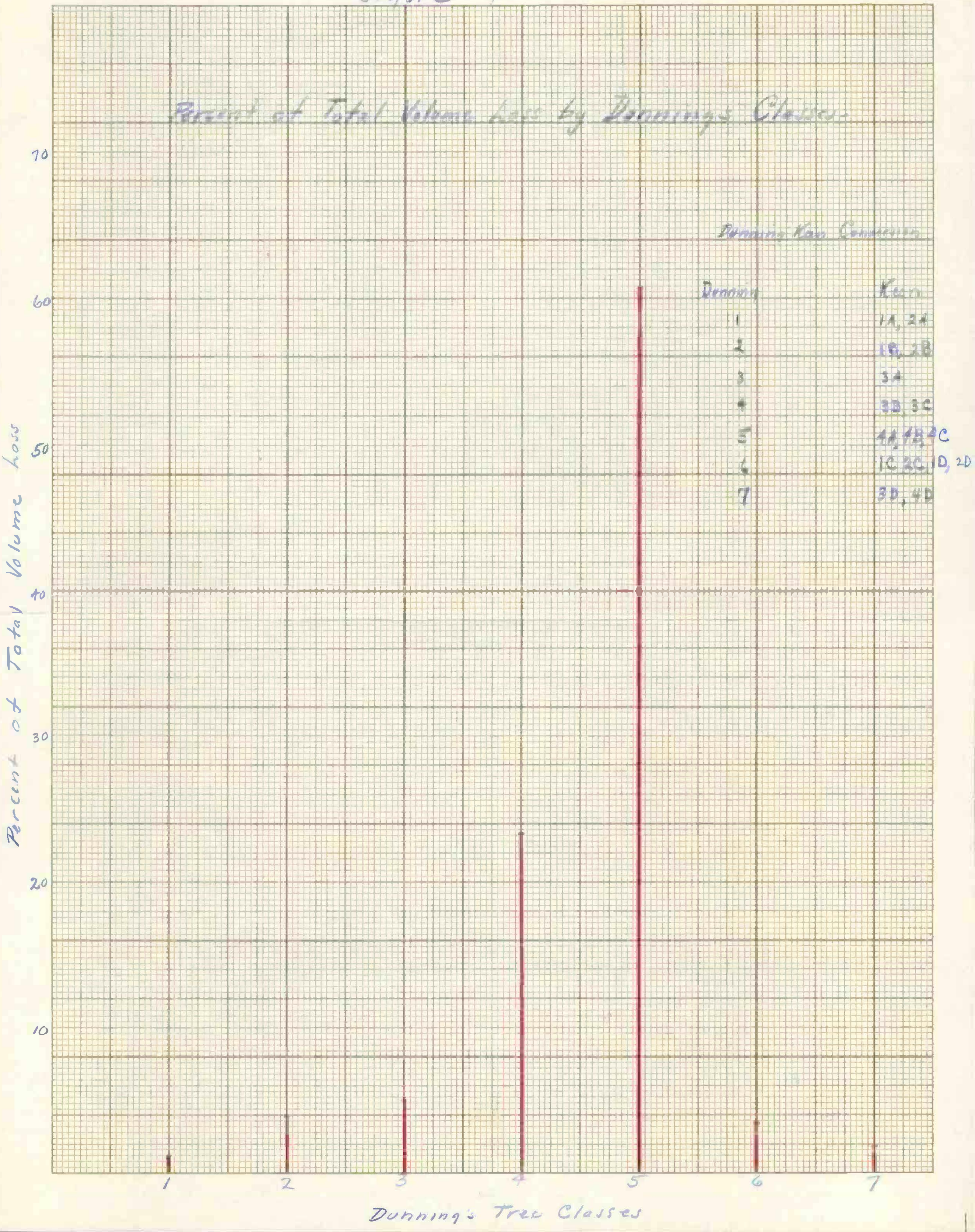


Figure 3
Percent
30
25
20
15
10
5
16 1A
15 2A
14 3A
13 4A
12 1B
11 2B
10 3B
9 4B
8 2D
7 4D
6 3D
5 1C
4 3C
3 4C
2 2C
1 1D

Figure 4


Percent of Total Volume Loss by Dunnings Classes.
Dunning Keen Conversion
Dunning
Keen
1
1A, 2A
2
1B, 2B
3
3A
4
3B, 3C
5
4A, 4B, 2C
6
1C, 2C, 1D, 2D
7
3D, 4D
Percent of Total Volume Loss
10
20
30
40
50
60
70
1
2
3
4
5
6
7
Dunning's Tree Classes